

N BARYONS

(S = 0, I = 1/2)

$$p, N^+ = uud; \quad n, N^0 = udd$$

NODE=BXXX005

p

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Mass $m = 1.00727646681 \pm 0.00000000009$ uMass $m = 938.272046 \pm 0.000021$ MeV [a]

$$|m_p - m_{\bar{p}}|/m_p < 2 \times 10^{-9}, \text{ CL} = 90\% [b]$$

$$|q_{\bar{p}}|/(q_p/m_p) = 0.99999999991 \pm 0.00000000009$$

$$|q_p + q_{\bar{p}}|/e < 2 \times 10^{-9}, \text{ CL} = 90\% [b]$$

$$|q_p + q_e|/e < 1 \times 10^{-21} [c]$$

Magnetic moment $\mu = 2.792847356 \pm 0.000000023$ μ_N

$$(\mu_p + \mu_{\bar{p}}) / \mu_p = (0 \pm 5) \times 10^{-6}$$

Electric dipole moment $d < 0.54 \times 10^{-23}$ e cm

$$\text{Electric polarizability } \alpha = (11.2 \pm 0.4) \times 10^{-4} \text{ fm}^3$$

$$\text{Magnetic polarizability } \beta = (2.5 \pm 0.4) \times 10^{-4} \text{ fm}^3 \quad (S = 1.2)$$

Charge radius, μp Lamb shift = 0.84087 ± 0.00039 fm [d]Charge radius, $e p$ CODATA value = 0.8775 ± 0.0051 fm [d]Magnetic radius = 0.777 ± 0.016 fmMean life $\tau > 2.1 \times 10^{29}$ years, CL = 90% [e] ($p \rightarrow$ invisible mode)Mean life $\tau > 10^{31}$ to 10^{33} years [e] (mode dependent)See the "Note on Nucleon Decay" in our 1994 edition (Phys. Rev. **D50**, 1173) for a short review.The "partial mean life" limits tabulated here are the limits on τ/B_j , where τ is the total mean life and B_j is the branching fraction for the mode in question. For N decays, p and n indicate proton and neutron partial lifetimes.

NODE=S016

NODE=S016AMU;DTYPE=M

NODE=S016M;DTYPE=M

NODE=S016DM;DTYPE=z

NODE=S016CMR;DTYPE=A

NODE=S016DQ2;DTYPE=Y

NODE=S016DQ;DTYPE=Y

NODE=S016MM;DTYPE=m

NODE=S016MMD;DTYPE=x

NODE=S016EDM;DTYPE=e

NODE=S016EPL;DTYPE=A

NODE=S016MPL;DTYPE=k

NODE=S016CRE;DTYPE=r;OUR EVAL;

→ UNCHECKED ←
NODE=S016CR;DTYPE=r

NODE=S016MCR;DTYPE=r

NODE=S016T;DTYPE=T

NODE=S016TX;DTYPE=T;OUR EST

NODE=S016225;NODE=S016

p DECAY MODES	Partial mean life (10^{30} years)	Confidence level	p (MeV/c)
Antilepton + meson			
$N \rightarrow e^+ \pi$	> 2000 (n), > 8200 (p)	90%	459
$N \rightarrow \mu^+ \pi$	> 1000 (n), > 6600 (p)	90%	453
$N \rightarrow \nu \pi$	> 112 (n), > 16 (p)	90%	459
$p \rightarrow e^+ \eta$	> 4200	90%	309
$p \rightarrow \mu^+ \eta$	> 1300	90%	297
$n \rightarrow \nu \eta$	> 158	90%	310
$N \rightarrow e^+ \rho$	> 217 (n), > 710 (p)	90%	149
$N \rightarrow \mu^+ \rho$	> 228 (n), > 160 (p)	90%	113
$N \rightarrow \nu \rho$	> 19 (n), > 162 (p)	90%	149
$p \rightarrow e^+ \omega$	> 320	90%	143
$p \rightarrow \mu^+ \omega$	> 780	90%	105
$n \rightarrow \nu \omega$	> 108	90%	144
$N \rightarrow e^+ K$	> 17 (n), > 1000 (p)	90%	339
$N \rightarrow \mu^+ K$	> 26 (n), > 1600 (p)	90%	329
$N \rightarrow \nu K$	> 86 (n), > 2300 (p)	90%	339
$n \rightarrow \nu K_S^0$	> 260	90%	338
$p \rightarrow e^+ K^*(892)^0$	> 84	90%	45
$N \rightarrow \nu K^*(892)$	> 78 (n), > 51 (p)	90%	45

NODE=S016;CLUMP=B

DESIG=6;OUR LIM

DESIG=7;OUR LIM

DESIG=10;OUR LIM

DESIG=22;OUR LIM

DESIG=23;OUR LIM

DESIG=24;OUR LIM

DESIG=14;OUR LIM

DESIG=15;OUR LIM

DESIG=25;OUR LIM

DESIG=12;OUR LIM

DESIG=13;OUR LIM

DESIG=26;OUR LIM

DESIG=8;OUR LIM

DESIG=9;OUR LIM

DESIG=11;OUR LIM

DESIG=99;OUR LIM

DESIG=34;OUR LIM

DESIG=18;OUR LIM

	Antilepton + mesons				
$p \rightarrow e^+ \pi^+ \pi^-$	> 82	90%	448	NODE=S016;CLUMP=E	
$p \rightarrow e^+ \pi^0 \pi^0$	> 147	90%	449	DESIG=56;OUR LIM	
$n \rightarrow e^+ \pi^- \pi^0$	> 52	90%	449	DESIG=57;OUR LIM	
$p \rightarrow \mu^+ \pi^+ \pi^-$	> 133	90%	425	DESIG=58;OUR LIM	
$p \rightarrow \mu^+ \pi^0 \pi^0$	> 101	90%	427	DESIG=48;OUR LIM	
$n \rightarrow \mu^+ \pi^- \pi^0$	> 74	90%	427	DESIG=59;OUR LIM	
$n \rightarrow e^+ K^0 \pi^-$	> 18	90%	319	DESIG=60;OUR LIM	
	Lepton + meson				
$n \rightarrow e^- \pi^+$	> 65	90%	459	NODE=S016;CLUMP=F	
$n \rightarrow \mu^- \pi^+$	> 49	90%	453	DESIG=29;OUR LIM	
$n \rightarrow e^- \rho^+$	> 62	90%	150	DESIG=30;OUR LIM	
$n \rightarrow \mu^- \rho^+$	> 7	90%	115	DESIG=31;OUR LIM	
$n \rightarrow e^- K^+$	> 32	90%	340	DESIG=32;OUR LIM	
$n \rightarrow \mu^- K^+$	> 57	90%	330	DESIG=33;OUR LIM	
	Lepton + mesons				
$p \rightarrow e^- \pi^+ \pi^+$	> 30	90%	448	NODE=S016;CLUMP=G	
$n \rightarrow e^- \pi^+ \pi^0$	> 29	90%	449	DESIG=47;OUR LIM	
$p \rightarrow \mu^- \pi^+ \pi^+$	> 17	90%	425	DESIG=39;OUR LIM	
$n \rightarrow \mu^- \pi^+ \pi^0$	> 34	90%	427	DESIG=49;OUR LIM	
$p \rightarrow e^- \pi^+ K^+$	> 75	90%	320	DESIG=40;OUR LIM	
$p \rightarrow \mu^- \pi^+ K^+$	> 245	90%	279	DESIG=41;OUR LIM	
	Antilepton + photon(s)				
$p \rightarrow e^+ \gamma$	> 670	90%	469	NODE=S016;CLUMP=C	
$p \rightarrow \mu^+ \gamma$	> 478	90%	463	DESIG=3;OUR LIM	
$n \rightarrow \nu \gamma$	> 28	90%	470	DESIG=4;OUR LIM	
$p \rightarrow e^+ \gamma \gamma$	> 100	90%	469	DESIG=5;OUR LIM	
$n \rightarrow \nu \gamma \gamma$	> 219	90%	470	DESIG=54;OUR LIM	
	Three (or more) leptons				
$p \rightarrow e^+ e^+ e^-$	> 793	90%	469	NODE=S016;CLUMP=D	
$p \rightarrow e^+ \mu^+ \mu^-$	> 359	90%	457	DESIG=16;OUR LIM	
$p \rightarrow e^+ \nu \nu$	> 17	90%	469	DESIG=45;OUR LIM	
$n \rightarrow e^+ e^- \nu$	> 257	90%	470	DESIG=36;OUR LIM	
$n \rightarrow \mu^+ e^- \nu$	> 83	90%	464	DESIG=27;OUR LIM	
$n \rightarrow \mu^+ \mu^- \nu$	> 79	90%	458	DESIG=37;OUR LIM	
$p \rightarrow \mu^+ e^+ e^-$	> 529	90%	463	DESIG=28;OUR LIM	
$p \rightarrow \mu^+ \mu^+ \mu^-$	> 675	90%	439	DESIG=55;OUR LIM	
$p \rightarrow \mu^+ \nu \nu$	> 21	90%	463	DESIG=17;OUR LIM	
$p \rightarrow e^- \mu^+ \mu^+$	> 6	90%	457	DESIG=38;OUR LIM	
$n \rightarrow 3\nu$	> 0.0005	90%	470	DESIG=46;OUR LIM	
	Inclusive modes				
$N \rightarrow e^+$ anything	> 0.6 (n, p)	90%	–	NODE=S016;CLUMP=A	
$N \rightarrow \mu^+$ anything	> 12 (n, p)	90%	–	DESIG=1;OUR LIM	
$N \rightarrow e^+ \pi^0$ anything	> 0.6 (n, p)	90%	–	DESIG=2;OUR LIM	
	$\Delta B = 2$ dinucleon modes				
				NODE=S016;CLUMP=I	
	The following are lifetime limits per iron nucleus.			NODE=S016	
$pp \rightarrow \pi^+ \pi^+$	> 0.7	90%	–	DESIG=62;OUR LIM	
$pn \rightarrow \pi^+ \pi^0$	> 2	90%	–	DESIG=63;OUR LIM	
$nn \rightarrow \pi^+ \pi^-$	> 0.7	90%	–	DESIG=64;OUR LIM	
$nn \rightarrow \pi^0 \pi^0$	> 3.4	90%	–	DESIG=65;OUR LIM	
$pp \rightarrow e^+ e^+$	> 5.8	90%	–	DESIG=66;OUR LIM	
$pp \rightarrow e^+ \mu^+$	> 3.6	90%	–	DESIG=67;OUR LIM	
$pp \rightarrow \mu^+ \mu^+$	> 1.7	90%	–	DESIG=68;OUR LIM	
$pn \rightarrow e^+ \bar{\nu}$	> 2.8	90%	–	DESIG=69;OUR LIM	
$pn \rightarrow \mu^+ \bar{\nu}$	> 1.6	90%	–	DESIG=70;OUR LIM	
$nn \rightarrow \nu_e \bar{\nu}_e$	> 1.4	90%	–	DESIG=71;OUR LIM	
$nn \rightarrow \nu_\mu \bar{\nu}_\mu$	> 1.4	90%	–	DESIG=72;OUR LIM	
$pn \rightarrow$ invisible	> 0.000021	90%	–	DESIG=101;OUR LIM	
$pp \rightarrow$ invisible	> 0.00005	90%	–	DESIG=100;OUR LIM	

\bar{p} DECAY MODES

\bar{p} DECAY MODES	Partial mean life (years)	Confidence level	p (MeV/c)
$\bar{p} \rightarrow e^- \gamma$	$> 7 \times 10^5$	90%	469
$\bar{p} \rightarrow \mu^- \gamma$	$> 5 \times 10^4$	90%	463
$\bar{p} \rightarrow e^- \pi^0$	$> 4 \times 10^5$	90%	459
$\bar{p} \rightarrow \mu^- \pi^0$	$> 5 \times 10^4$	90%	453
$\bar{p} \rightarrow e^- \eta$	$> 2 \times 10^4$	90%	309
$\bar{p} \rightarrow \mu^- \eta$	$> 8 \times 10^3$	90%	297
$\bar{p} \rightarrow e^- K_S^0$	> 900	90%	337
$\bar{p} \rightarrow \mu^- K_S^0$	$> 4 \times 10^3$	90%	326
$\bar{p} \rightarrow e^- K_L^0$	$> 9 \times 10^3$	90%	337
$\bar{p} \rightarrow \mu^- K_L^0$	$> 7 \times 10^3$	90%	326
$\bar{p} \rightarrow e^- \gamma \gamma$	$> 2 \times 10^4$	90%	469
$\bar{p} \rightarrow \mu^- \gamma \gamma$	$> 2 \times 10^4$	90%	463
$\bar{p} \rightarrow e^- \omega$	> 200	90%	143

NODE=S016;CLUMP=M
NODE=S016

 n

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Mass $m = 1.0086649160 \pm 0.0000000004$ u
 Mass $m = 939.565379 \pm 0.000021$ MeV [a]
 $(m_n - m_{\bar{n}}) / m_n = (9 \pm 6) \times 10^{-5}$
 $m_n - m_p = 1.2933322 \pm 0.0000004$ MeV
 $= 0.00138844919(45)$ u
 Mean life $\tau = 880.0 \pm 0.9$ s ($S = 1.4$)
 $c\tau = 2.6381 \times 10^8$ km
 Magnetic moment $\mu = -1.9130427 \pm 0.0000005$ μ_N
 Electric dipole moment $d < 0.29 \times 10^{-25}$ ecm, CL = 90%
 Mean-square charge radius $\langle r_n^2 \rangle = -0.1161 \pm 0.0022$
 fm^2 ($S = 1.3$)
 Magnetic radius $\sqrt{\langle r_M^2 \rangle} = 0.862_{-0.008}^{+0.009}$ fm
 Electric polarizability $\alpha = (11.6 \pm 1.5) \times 10^{-4}$ fm^3
 Magnetic polarizability $\beta = (3.7 \pm 2.0) \times 10^{-4}$ fm^3
 Charge $q = (-0.2 \pm 0.8) \times 10^{-21}$ e
 Mean $n\bar{n}$ -oscillation time $> 8.6 \times 10^7$ s, CL = 90% (free n)
 Mean $n\bar{n}$ -oscillation time $> 1.3 \times 10^8$ s, CL = 90% [f] (bound n)
 Mean nn' -oscillation time > 414 s, CL = 90% [g]

 $p e^- \nu_e$ decay parameters [h]

$\lambda \equiv g_A / g_V = -1.2701 \pm 0.0025$ ($S = 1.9$)
 $A = -0.1176 \pm 0.0011$ ($S = 2.1$)
 $B = 0.9807 \pm 0.0030$
 $C = -0.2377 \pm 0.0026$
 $a = -0.103 \pm 0.004$
 $\phi_{AV} = (180.017 \pm 0.026)^\circ$ [i]
 $D = (-1.2 \pm 2.0) \times 10^{-4}$ [j]
 $R = 0.004 \pm 0.013$ [j]

NODE=S017

NODE=S017AMU;DTYPE=M
 NODE=S017M;DTYPE=M
 NODE=S017DMM;DTYPE=D;OUR EVAL
 NODE=S017D;DTYPE=D
 NODE=S017DX;DTYPE=D;OUR EST
 NODE=S017T;DTYPE=T
 NODE=S017CTA;DTYPE=C;OUR EVAL
 NODE=S017MM;DTYPE=m
 NODE=S017EDM;DTYPE=e
 NODE=S017MCR;DTYPE=r
 NODE=S017MRD;DTYPE=r
 NODE=S017EPL;DTYPE=A
 NODE=S017MPL;DTYPE=k
 NODE=S017Q;DTYPE=Y
 NODE=S017NAN;DTYPE=N
 NODE=S017NAX;DTYPE=N;OUR LIM
 NODE=S017NOS;DTYPE=o

CLUMP=D

NODE=S017AV;DTYPE=d;CLUMP=D
 NODE=S017BA;DTYPE=d;CLUMP=D
 NODE=S017NA;DTYPE=d;CLUMP=D
 NODE=S017APC;DTYPE=d;CLUMP=D
 NODE=S017BNC;DTYPE=d;CLUMP=D
 NODE=S017F;DTYPE=d;CLUMP=D
 NODE=S017D1;DTYPE=d;CLUMP=D
 NODE=S017TCC;DTYPE=d;CLUMP=D

<i>n</i> DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$p e^- \bar{\nu}_e$	100	%	1
$p e^- \bar{\nu}_e \gamma$	[k] (3.09 ± 0.32) $\times 10^{-3}$		1
Charge conservation (Q) violating mode			
$p \nu_e \bar{\nu}_e$	Q < 8	$\times 10^{-27}$	68% 1

NODE=S017245;DESIG=1;OUR EVAL;
UNCHECKED ←
DESIG=4

NODE=S017;CLUMP=A
DESIG=2

$N(1440) 1/2^+$

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Breit-Wigner mass = 1420 to 1470 (≈ 1440) MeV
 Breit-Wigner full width = 200 to 450 (≈ 300) MeV
 $p_{\text{beam}} = 0.61 \text{ GeV}/c$ $4\pi\lambda^2 = 31.0 \text{ mb}$
 Re(pole position) = 1350 to 1380 (≈ 1365) MeV
 $-2\text{Im}(\text{pole position}) = 160 \text{ to } 220$ (≈ 190) MeV

NODE=B061

NODE=B061M;DTYPE=M;OUR EST;
UNCHECKED ←
NODE=B061W;DTYPE=G;OUR EST;
UNCHECKED ←
NODE=B061PB;DTYPE=P;OUR EVAL
NODE=B061RE;DTYPE=i;OUR EST;
UNCHECKED ←
NODE=B061IM;DTYPE=i;OUR EST;
UNCHECKED ←
NODE=B061230;NODE=B061

$N(1440)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	55–75 %	398
$N\eta$	(0.0 ± 1.0) %	†
$N\pi\pi$	30–40 %	347
$\Delta\pi$	20–30 %	147
$\Delta(1232)\pi$, <i>P</i> -wave	15–30 %	147
$N\rho$	<8 %	†
$N\rho$, <i>S</i> =1/2, <i>P</i> -wave	(0.0 ± 1.0) %	†
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	10–20 %	–
$p\gamma$	0.035–0.048 %	414
$p\gamma$, helicity=1/2	0.035–0.048 %	414
$n\gamma$	0.02–0.04 %	413
$n\gamma$, helicity=1/2	0.02–0.04 %	413

DESIG=1;OUR EST

DESIG=2

DESIG=4;OUR EST

DESIG=181;OUR EST

DESIG=5;OUR EST

DESIG=182;OUR EST

DESIG=6

DESIG=8;OUR EST

DESIG=184;OUR EST

DESIG=9;OUR EST

DESIG=185;OUR EST

DESIG=10;OUR EST

$N(1520) 3/2^-$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

Breit-Wigner mass = 1515 to 1525 (≈ 1520) MeV
 Breit-Wigner full width = 100 to 125 (≈ 115) MeV
 $p_{\text{beam}} = 0.74 \text{ GeV}/c$ $4\pi\lambda^2 = 23.5 \text{ mb}$
 Re(pole position) = 1505 to 1515 (≈ 1510) MeV
 $-2\text{Im}(\text{pole position}) = 105 \text{ to } 120$ (≈ 110) MeV

NODE=B062

NODE=B062M;DTYPE=M;OUR EST;
UNCHECKED ←
NODE=B062W;DTYPE=G;OUR EST;
UNCHECKED ←
NODE=B062PB;DTYPE=P;OUR EVAL
NODE=B062RE;DTYPE=i;OUR EST;
UNCHECKED ←
NODE=B062IM;DTYPE=i;OUR EST;
UNCHECKED ←

N(1520) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	NODE=B062225;NODE=B062
$N\pi$	55–65 %	457	DESIG=1;OUR EST
$N\eta$	$(2.3\pm 0.4) \times 10^{-3}$	154	DESIG=2
$N\pi\pi$	20–30 %	414	DESIG=4;OUR EST
$\Delta\pi$	15–25 %	230	DESIG=181;OUR EST
$\Delta(1232)\pi$, S -wave	10–20 %	230	DESIG=5;OUR EST
$\Delta(1232)\pi$, D -wave	10–15 %	230	DESIG=6;OUR EST
$N\rho$	15–25 %	†	DESIG=182;OUR EST
$N\rho$, $S=3/2$, S -wave	(9.0 ± 1.0) %	†	DESIG=8
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	<8 %	–	DESIG=10;OUR EST
$p\gamma$	0.31–0.52 %	470	DESIG=184;OUR EST
$p\gamma$, helicity=1/2	0.01–0.02 %	470	DESIG=11;OUR EST
$p\gamma$, helicity=3/2	0.30–0.50 %	470	DESIG=12;OUR EST
$n\gamma$	0.30–0.53 %	470	DESIG=185;OUR EST
$n\gamma$, helicity=1/2	0.04–0.10 %	470	DESIG=13;OUR EST
$n\gamma$, helicity=3/2	0.25–0.45 %	470	DESIG=14;OUR EST

N(1535) 1/2⁻

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^-)$$

Breit-Wigner mass = 1525 to 1545 (≈ 1535) MeV
 Breit-Wigner full width = 125 to 175 (≈ 150) MeV
 $p_{\text{beam}} = 0.76$ GeV/c $4\pi\lambda^2 = 22.5$ mb
 Re(pole position) = 1490 to 1530 (≈ 1510) MeV
 $-2\text{Im}(\text{pole position}) = 90$ to 250 (≈ 170) MeV

NODE=B063

NODE=B063M;DTYPE=M;OUR EST;
 \rightarrow UNCHECKED \leftarrow
 NODE=B063W;DTYPE=G;OUR EST;
 \rightarrow UNCHECKED \leftarrow
 NODE=B063PB;DTYPE=P;OUR EVAL
 \rightarrow UNCHECKED \leftarrow
 NODE=B063RE;DTYPE=i;OUR EST;
 \rightarrow UNCHECKED \leftarrow
 NODE=B063IM;DTYPE=i;OUR EST;
 \rightarrow UNCHECKED \leftarrow
 NODE=B063225;NODE=B063

N(1535) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	
$N\pi$	35–55 %	468	DESIG=1;OUR EST
$N\eta$	(42 ± 10) %	186	DESIG=2;OUR EST
$N\pi\pi$	1–10 %	426	DESIG=4;OUR EST
$\Delta\pi$	<1 %	244	DESIG=181;OUR EST
$\Delta(1232)\pi$, D -wave	0–4 %	244	DESIG=5;OUR EST
$N\rho$	<4 %	†	DESIG=182;OUR EST
$N\rho$, $S=1/2$, S -wave	(2.0 ± 1.0) %	†	DESIG=6
$N\rho$, $S=3/2$, D -wave	(0.0 ± 1.0) %	†	DESIG=7
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	(2 ± 1) %	–	DESIG=8;OUR EST
$N(1440)\pi$	(8 ± 3) %	†	DESIG=11;OUR EST
$p\gamma$	0.15–0.30 %	481	DESIG=184;OUR EST
$p\gamma$, helicity=1/2	0.15–0.30 %	481	DESIG=9;OUR EST
$n\gamma$	0.01–0.25 %	480	DESIG=185;OUR EST
$n\gamma$, helicity=1/2	0.01–0.25 %	480	DESIG=10;OUR EST

N(1650) 1/2⁻

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^-)$$

Breit-Wigner mass = 1645 to 1670 (≈ 1655) MeV
 Breit-Wigner full width = 120 to 180 (≈ 150) MeV
 $p_{\text{beam}} = 0.97$ GeV/c $4\pi\lambda^2 = 16.2$ mb
 Re(pole position) = 1640 to 1670 (≈ 1655) MeV
 $-2\text{Im}(\text{pole position}) = 100$ to 170 (≈ 135) MeV

NODE=B066

NODE=B066M;DTYPE=M;OUR EST;
 \rightarrow UNCHECKED \leftarrow
 NODE=B066W;DTYPE=G;OUR EST;
 \rightarrow UNCHECKED \leftarrow
 NODE=B066PB;DTYPE=P;OUR EVAL
 \rightarrow UNCHECKED \leftarrow
 NODE=B066RE;DTYPE=i;OUR EST;
 \rightarrow UNCHECKED \leftarrow
 NODE=B066IM;DTYPE=i;OUR EST;
 \rightarrow UNCHECKED \leftarrow

N(1650) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	NODE=B066225;NODE=B066
$N\pi$	50–90 %	551	DESIG=1;OUR EST
$N\eta$	5–15 %	354	DESIG=2;OUR EST
ΛK	3–11 %	179	DESIG=3;OUR EST
$N\pi\pi$	10–20 %	517	DESIG=5;OUR EST
$\Delta\pi$	0–25 %	349	DESIG=181;OUR EST
$\Delta(1232)\pi$, D -wave	0–25 %	349	DESIG=6;OUR EST
$N\rho$	4–12 %	†	DESIG=182;OUR EST
$N\rho$, $S=1/2$, S -wave	(1.0±1.0) %	†	DESIG=7
$N\rho$, $S=3/2$, D -wave	(13.0±3.0) %	†	DESIG=8
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	<4 %	–	DESIG=9;OUR EST
$N(1440)\pi$	<5 %	156	DESIG=10;OUR EST
$p\gamma$	0.04–0.20 %	562	DESIG=184;OUR EST
$p\gamma$, helicity=1/2	0.04–0.20 %	562	DESIG=11;OUR EST
$n\gamma$	0.003–0.17 %	561	DESIG=185;OUR EST
$n\gamma$, helicity=1/2	0.003–0.17 %	561	DESIG=12;OUR EST

N(1675) 5/2⁻

$$I(J^P) = \frac{1}{2}(\frac{5}{2}^-)$$

Breit-Wigner mass = 1670 to 1680 (\approx 1675) MeV
 Breit-Wigner full width = 130 to 165 (\approx 150) MeV
 $p_{\text{beam}} = 1.01$ GeV/c $4\pi\lambda^2 = 15.4$ mb
 Re(pole position) = 1655 to 1665 (\approx 1660) MeV
 $-2\text{Im}(\text{pole position}) = 125$ to 150 (\approx 135) MeV

NODE=B064

NODE=B064M;DTYPE=M;OUR EST;
 → UNCHECKED ←
 NODE=B064W;DTYPE=G;OUR EST;
 → UNCHECKED ←
 NODE=B064RB;DTYPE=P;OUR EVAL
 NODE=B064RE;DTYPE=i;OUR EST;
 → UNCHECKED ←
 NODE=B064IM;DTYPE=i;OUR EST;
 → UNCHECKED ←
 NODE=B064225;NODE=B064

N(1675) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	
$N\pi$	35–45 %	564	DESIG=1;OUR EST
$N\eta$	(0.0± 1.0) %	376	DESIG=2
ΛK	<1 %	216	DESIG=3;OUR EST
$N\pi\pi$	50–60 %	532	DESIG=5;OUR EST
$\Delta\pi$	50–60 %	366	DESIG=181;OUR EST
$\Delta(1232)\pi$, D -wave	(50 ±15) %	366	DESIG=6
$N\rho$	< 1–3 %	†	DESIG=182;OUR EST
$N\rho$, $S=1/2$, D -wave	(0.0± 1.0) %	†	DESIG=8
$N\rho$, $S=3/2$, D -wave	(1.0± 1.0) %	†	DESIG=9
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	(7.0± 3.0) %	–	DESIG=11
$p\gamma$	0–0.02 %	575	DESIG=184;OUR EST
$p\gamma$, helicity=1/2	0–0.01 %	575	DESIG=13;OUR EST
$p\gamma$, helicity=3/2	0–0.01 %	575	DESIG=14;OUR EST
$n\gamma$	0–0.15 %	574	DESIG=185;OUR EST
$n\gamma$, helicity=1/2	0–0.05 %	574	DESIG=15;OUR EST
$n\gamma$, helicity=3/2	0–0.10 %	574	DESIG=16;OUR EST

N(1680) 5/2⁺

$$I(J^P) = \frac{1}{2}(\frac{5}{2}^+)$$

Breit-Wigner mass = 1680 to 1690 (\approx 1685) MeV
 Breit-Wigner full width = 120 to 140 (\approx 130) MeV
 $p_{\text{beam}} = 1.02$ GeV/c $4\pi\lambda^2 = 15.0$ mb
 Re(pole position) = 1665 to 1680 (\approx 1675) MeV
 $-2\text{Im}(\text{pole position}) = 110$ to 135 (\approx 120) MeV

NODE=B065

NODE=B065M;DTYPE=M;OUR EST;
 → UNCHECKED ←
 NODE=B065W;DTYPE=G;OUR EST;
 → UNCHECKED ←
 NODE=B065RB;DTYPE=P;OUR EVAL
 NODE=B065RE;DTYPE=i;OUR EST;
 → UNCHECKED ←
 NODE=B065IM;DTYPE=i;OUR EST;
 → UNCHECKED ←

N(1680) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	NODE=B065225;NODE=B065
$N\pi$	65–70 %	571	DESIG=1;OUR EST
$N\eta$	(0.0±1.0) %	386	DESIG=2
$N\pi\pi$	30–40 %	539	DESIG=5;OUR EST
$\Delta\pi$	5–15 %	374	DESIG=181;OUR EST
$\Delta(1232)\pi$, P -wave	(10 ±5) %	374	DESIG=6;OUR EST
$\Delta(1232)\pi$, F -wave	0–12 %	374	DESIG=7;OUR EST
$N\rho$	3–15 %	†	DESIG=182;OUR EST
$N\rho$, $S=3/2$, P -wave	<12;%	†	DESIG=9;OUR EST
$N\rho$, $S=3/2$, F -wave	1–5 %	†	DESIG=10;OUR EST
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	(11 ±5) %	–	DESIG=11;OUR EST
$p\gamma$	0.21–0.32 %	581	DESIG=184;OUR EST
$p\gamma$, helicity=1/2	0.001–0.011 %	581	DESIG=12;OUR EST
$p\gamma$, helicity=3/2	0.20–0.32 %	581	DESIG=13;OUR EST
$n\gamma$	0.021–0.046 %	581	DESIG=185;OUR EST
$n\gamma$, helicity=1/2	0.004–0.029 %	581	DESIG=14;OUR EST
$n\gamma$, helicity=3/2	0.01–0.024 %	581	DESIG=15;OUR EST

N(1700) 3/2⁻

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

Breit-Wigner mass = 1650 to 1750 (\approx 1700) MeV
 Breit-Wigner full width = 100 to 250 (\approx 150) MeV
 $p_{\text{beam}} = 1.05$ GeV/c $4\pi\lambda^2 = 14.5$ mb
 Re(pole position) = 1650 to 1750 (\approx 1700) MeV
 $-2\text{Im}(\text{pole position}) = 100$ to 300 MeV

NODE=B018

NODE=B018M;DTYPE=M;OUR EST;
 → UNCHECKED ←
 NODE=B018W;DTYPE=G;OUR EST;
 → UNCHECKED ←
 NODE=B018PB;DTYPE=P;OUR EVAL
 → UNCHECKED ←
 NODE=B018RE;DTYPE=i;OUR EST;
 → UNCHECKED ←
 NODE=B018IM;DTYPE=i;OUR EST;
 → UNCHECKED ←
 NODE=B018225;NODE=B018

N(1700) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	NODE=B018225;NODE=B018
$N\pi$	(12 ±5) %	581	DESIG=1;OUR EST
$N\eta$	(0.0±1.0) %	402	DESIG=2
ΛK	< 3 %	255	DESIG=3;OUR EST
$N\pi\pi$	85–95 %	550	DESIG=171;OUR EST
$\Delta(1232)\pi$, S -wave	10–90 %	386	DESIG=5;OUR EST
$\Delta(1232)\pi$, D -wave	< 20 %	386	DESIG=6
$N\rho$	< 35 %	†	DESIG=182;OUR EST
$N\rho$, $S=3/2$, S -wave	(7.0±1.0) %	†	DESIG=8
$p\gamma$	0.01–0.05 %	591	DESIG=184;OUR EST
$p\gamma$, helicity=1/2	0.0–0.024 %	591	DESIG=11;OUR EST
$p\gamma$, helicity=3/2	0.002–0.026 %	591	DESIG=12;OUR EST
$n\gamma$	0.01–0.13 %	590	DESIG=185;OUR EST
$n\gamma$, helicity=1/2	0.0–0.09 %	590	DESIG=13;OUR EST
$n\gamma$, helicity=3/2	0.01–0.05 %	590	DESIG=14;OUR EST

N(1710) 1/2⁺

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Breit-Wigner mass = 1680 to 1740 (\approx 1710) MeV
 Breit-Wigner full width = 50 to 250 (\approx 100) MeV
 $p_{\text{beam}} = 1.07$ GeV/c $4\pi\lambda^2 = 14.2$ mb
 Re(pole position) = 1670 to 1770 (\approx 1720) MeV
 $-2\text{Im}(\text{pole position}) = 80$ to 380 (\approx 230) MeV

NODE=B014

NODE=B014M;DTYPE=M;OUR EST;
 → UNCHECKED ←
 NODE=B014W;DTYPE=G;OUR EST;
 → UNCHECKED ←
 NODE=B014PB;DTYPE=P;OUR EVAL
 → UNCHECKED ←
 NODE=B014RE;DTYPE=i;OUR EST;
 → UNCHECKED ←
 NODE=B014IM;DTYPE=i;OUR EST;
 → UNCHECKED ←

N(1710) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	NODE=B014225;NODE=B014
$N\pi$	5–20 %	588	DESIG=1;OUR EST
$N\eta$	10–30 %	412	DESIG=2;OUR EST
$N\omega$	(13.0±2.0) %	†	DESIG=12
ΛK	5–25 %	269	DESIG=3;OUR EST
$N\pi\pi$	40–90 %	557	DESIG=5;OUR EST
$\Delta\pi$	15–40 %	394	DESIG=181;OUR EST
$N\rho$	5–25 %	†	DESIG=182;OUR EST
$N(\pi\pi)_{S=0}^{I=0}$	10–40 %	–	DESIG=9;OUR EST
$p\gamma$	0.002–0.08 %	598	DESIG=184;OUR EST
$p\gamma$, helicity=1/2	0.002–0.08 %	598	DESIG=10;OUR EST
$n\gamma$	0.0–0.02%	597	DESIG=186;OUR EST
$n\gamma$, helicity=1/2	0.0–0.02%	597	DESIG=11;OUR EST

N(1720) 3/2⁺

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$$

Breit-Wigner mass = 1700 to 1750 (\approx 1720) MeV
 Breit-Wigner full width = 150 to 400 (\approx 250) MeV
 $p_{\text{beam}} = 1.09$ GeV/c $4\pi\lambda^2 = 13.9$ mb
 Re(pole position) = 1660 to 1690 (\approx 1675) MeV
 $-2\text{Im}(\text{pole position}) = 150$ to 400 (\approx 250) MeV

N(1720) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	NODE=B015
$N\pi$	(11± 3) %	594	DESIG=1;OUR EST
$N\eta$	(4± 1) %	422	DESIG=2;OUR EST
ΛK	1–15 %	283	DESIG=3;OUR EST
$N\pi\pi$	>70 %	564	DESIG=5;OUR EST
$\Delta(1232)\pi$, P -wave	(75±15) %	402	DESIG=6
$N\rho$	70–85 %	74	DESIG=182;OUR EST
$N\rho$, $S=1/2$, P -wave	large	74	DESIG=7;OUR EST
$p\gamma$	0.05–0.25 %	604	DESIG=184;OUR EST
$p\gamma$, helicity=1/2	0.05–0.15 %	604	DESIG=10;OUR EST
$p\gamma$, helicity=3/2	0.002–0.16 %	604	DESIG=11;OUR EST
$n\gamma$	0.0–0.016 %	603	DESIG=185;OUR EST
$n\gamma$, helicity=1/2	0.0–0.01 %	603	DESIG=12;OUR EST
$n\gamma$, helicity=3/2	0.0–0.015 %	603	DESIG=13;OUR EST

N(1875) 3/2⁻

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

Breit-Wigner mass = 1820 to 1920 (\approx 1875) MeV
 Breit-Wigner full width = 160 to 320 (\approx 220) MeV
 Re(pole position) = 1800 to 1950 MeV
 $-2\text{Im}(\text{pole position}) = 150$ to 250 MeV

NODE=B015

NODE=B015M;DTYPE=M;OUR EST;
 → UNCHECKED ←
 NODE=B015W;DTYPE=G;OUR EST;
 → UNCHECKED ←
 NODE=B015PB;DTYPE=P;OUR EVAL
 NODE=B015RE;DTYPE=i;OUR EST;
 → UNCHECKED ←
 NODE=B015IM;DTYPE=i;OUR EST;
 → UNCHECKED ←
 NODE=B015225;NODE=B015

NODE=B016

NODE=B016M;DTYPE=M;OUR EST;
 → UNCHECKED ←
 NODE=B016W;DTYPE=G;OUR EST;
 → UNCHECKED ←
 NODE=B016RE;DTYPE=p;OUR EST;
 → UNCHECKED ←
 NODE=B016IM;DTYPE=p;OUR EST;
 → UNCHECKED ←

N(1875) DECAY MODES	Fraction (Γ_i/Γ)	Scale factor	p (MeV/c)
$N\pi$	(12 \pm 10) %		695
$N\eta$	(3.5 \pm 3.5) %	2.5	559
$N\omega$	(21 \pm 7) %		371
ΣK	(7 \pm 4) $\times 10^{-3}$		384
$\Delta(1232)\pi$, S-wave	(40 \pm 10) %		520
$\Delta(1232)\pi$, D-wave	(17 \pm 10) %		520
$N\rho$, S=3/2, S-wave	(6 \pm 6) %		379
$N(\pi\pi)_{S\text{-wave}}^{I=0}$	(24 \pm 24) %		—
$p\gamma$	0.008–0.016 %		703
$p\gamma$, helicity=1/2	0.006–0.010 %		703
$p\gamma$, helicity=3/2	0.002–0.006 %		703

NODE=B016225;DESIG=1
DESIG=2
DESIG=12
DESIG=4
DESIG=21
DESIG=22
DESIG=23
DESIG=24
DESIG=10;OUR EST
DESIG=6;OUR EST
DESIG=7;OUR EST

N(1900) 3/2⁺

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$$

Breit-Wigner mass \approx 1900 MeV
Breit-Wigner full width \sim 250 MeV
Re(pole position) = 1900 \pm 30 MeV
 $-2\text{Im}(\text{pole position}) = 200_{-60}^{+100}$ MeV

NODE=B144

NODE=B144M;DTYPE=M;OUR EST;
→ UNCHECKED ←
NODE=B144W;DTYPE=G;OUR EST;
→ UNCHECKED ←
NODE=B144RE;DTYPE=p
NODE=B144IM;DTYPE=p

N(1900) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	\sim 10 %	710
$N\eta$	\sim 12 %	579
$N\omega$	(39 \pm 9) %	401
ΛK	0–10 %	477
ΣK	(5.0 \pm 2.0) %	410

NODE=B144215;DESIG=1
DESIG=4
DESIG=5
DESIG=6;OUR EST
DESIG=7

N(2190) 7/2⁻

$$I(J^P) = \frac{1}{2}(\frac{7}{2}^-)$$

Breit-Wigner mass = 2100 to 2200 (\approx 2190) MeV
Breit-Wigner full width = 300 to 700 (\approx 500) MeV
 $p_{\text{beam}} = 2.07$ GeV/c $4\pi\lambda^2 = 6.21$ mb
Re(pole position) = 2050 to 2100 (\approx 2075) MeV
 $-2\text{Im}(\text{pole position}) = 400$ to 520 (\approx 450) MeV

NODE=B071

NODE=B071M;DTYPE=M;OUR EST;
→ UNCHECKED ←
NODE=B071W;DTYPE=G;OUR EST;
→ UNCHECKED ←
NODE=B071RB;DTYPE=P;OUR EVAL
NODE=B071RE;DTYPE=i;OUR EST;
→ UNCHECKED ←
NODE=B071IM;DTYPE=i;OUR EST;
→ UNCHECKED ←
NODE=B071225;NODE=B071

N(2190) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	10–20 %	888
$N\eta$	(0.0 \pm 1.0) %	791
$N\omega$	seen	676
ΛK	seen	712
$N\pi\pi$	seen	870
$N\rho$	seen	680
$p\gamma$	0.02–0.06 %	894
$p\gamma$, helicity=1/2	0.02–0.04 %	894
$p\gamma$, helicity=3/2	0.002–0.02 %	894

DESIG=1;OUR EST
DESIG=2
DESIG=178
DESIG=3;OUR EVAL
DESIG=5;OUR EVAL
DESIG=14;OUR EVAL
DESIG=11;OUR EST
DESIG=7;OUR EST
DESIG=8;OUR EST

N(2220) 9/2⁺

$$I(J^P) = \frac{1}{2}(\frac{9}{2}^+)$$

Breit-Wigner mass = 2200 to 2300 (\approx 2250) MeV
Breit-Wigner full width = 350 to 500 (\approx 400) MeV
 $p_{\text{beam}} = 2.21$ GeV/c $4\pi\lambda^2 = 5.74$ mb
Re(pole position) = 2130 to 2200 (\approx 2170) MeV
 $-2\text{Im}(\text{pole position}) = 400$ to 560 (\approx 480) MeV

NODE=B090

NODE=B090M;DTYPE=M;OUR EST;
→ UNCHECKED ←
NODE=B090W;DTYPE=G;OUR EST;
→ UNCHECKED ←
NODE=B090RB;DTYPE=P;OUR EVAL
NODE=B090RE;DTYPE=i;OUR EST;
→ UNCHECKED ←
NODE=B090IM;DTYPE=i;OUR EST;
→ UNCHECKED ←

N(2220) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	15–25 %	924

NODE=B090225;NODE=B090

DESIG=1;OUR EST

N(2250) 9/2⁻

$$I(J^P) = \frac{1}{2}(\frac{9}{2}^-)$$

Breit-Wigner mass = 2200 to 2350 (≈ 2275) MeVBreit-Wigner full width = 230 to 800 (≈ 500) MeV

$$p_{\text{beam}} = 2.27 \text{ GeV}/c \quad 4\pi\lambda^2 = 5.56 \text{ mb}$$

Re(pole position) = 2150 to 2250 (≈ 2200) MeV $-2\text{Im}(\text{pole position}) = 350$ to 550 (≈ 450) MeV

NODE=B113

NODE=B113M;DTYPE=M;OUR EST;
 → UNCHECKED ←
 NODE=B113W;DTYPE=G;OUR EST;
 → UNCHECKED ←
 NODE=B113PB;DTYPE=P;OUR EVAL
 → UNCHECKED ←
 NODE=B113RE;DTYPE=i;OUR EST;
 → UNCHECKED ←
 NODE=B113IM;DTYPE=i;OUR EST;
 → UNCHECKED ←
 NODE=B113225;NODE=B113

N(2250) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	5–15 %	938

DESIG=1;OUR EST

N(2600) 11/2⁻

$$I(J^P) = \frac{1}{2}(\frac{11}{2}^-)$$

Breit-Wigner mass = 2550 to 2750 (≈ 2600) MeVBreit-Wigner full width = 500 to 800 (≈ 650) MeV

$$p_{\text{beam}} = 3.12 \text{ GeV}/c \quad 4\pi\lambda^2 = 3.86 \text{ mb}$$

NODE=B120

NODE=B120M;DTYPE=M;OUR EST;
 → UNCHECKED ←
 NODE=B120W;DTYPE=G;OUR EST;
 → UNCHECKED ←
 NODE=B120PB;DTYPE=P;OUR EVAL

N(2600) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	5–10 %	1126

NODE=B120215;DESIG=1;OUR EST

NOTES

- [a] The masses of the p and n are most precisely known in u (unified atomic mass units). The conversion factor to MeV, $1 \text{ u} = 931.494061(21) \text{ MeV}$, is less well known than are the masses in u.
- [b] The $|m_p - m_{\bar{p}}|/m_p$ and $|q_p + q_{\bar{p}}|/e$ are not independent, and both use the more precise measurement of $|q_{\bar{p}}/m_{\bar{p}}|/(q_p/m_p)$.
- [c] The limit is from neutrality-of-matter experiments; it assumes $q_n = q_p + q_e$. See also the charge of the neutron.
- [d] The μp and $e p$ values for the charge radius are much too different to average them. The disagreement is not yet understood.
- [e] The first limit is for $p \rightarrow$ anything or "disappearance" modes of a bound proton. The second entry, a rough range of limits, assumes the dominant decay modes are among those investigated. For antiprotons the best limit, inferred from the observation of cosmic ray \bar{p} 's is $\tau_{\bar{p}} > 10^7$ yr, the cosmic-ray storage time, but this limit depends on a number of assumptions. The best direct observation of stored antiprotons gives $\tau_{\bar{p}}/B(\bar{p} \rightarrow e^- \gamma) > 7 \times 10^5$ yr.
- [f] There is some controversy about whether nuclear physics and model dependence complicate the analysis for bound neutrons (from which the best limit comes). The first limit here is from reactor experiments with free neutrons.
- [g] Lee and Yang in 1956 proposed the existence of a mirror world in an attempt to restore global parity symmetry—thus a search for oscillations between the two worlds. Oscillations between the worlds would be maximal when the magnetic fields B and B' were equal. The limit for any B' in the range 0 to $12.5 \mu\text{T}$ is >12 s (95% CL).
- [h] The parameters g_A , g_V , and g_{WM} for semileptonic modes are defined by $\bar{B}_f[\gamma_\lambda(g_V + g_A\gamma_5) + i(g_{WM}/m_{B_i}) \sigma_{\lambda\nu} q^\nu]B_i$, and ϕ_{AV} is defined by

LINKAGE=SEB

LINKAGE=MQ

LINKAGE=SS

LINKAGE=CHR

LINKAGE=SR

LINKAGE=SNN

LINKAGE=NOS

LINKAGE=SBD

$g_A/g_V = |g_A/g_V|e^{i\phi_{AV}}$. See the "Note on Baryon Decay Parameters" in the neutron Particle Listings.

[i] Time-reversal invariance requires this to be 0° or 180° .

[j] This coefficient is zero if time invariance is not violated.

[k] This limit is for γ energies between 15 and 340 keV.

LINKAGE=CR

LINKAGE=TVC

LINKAGE=GL